

Original Article

Changes in mitral annular morphology and function in young patients with type 1 diabetes mellitus—results from the three-dimensional speckle tracking echocardiographic MAGYAR-Path Study

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Background: Alterations in mitral annular size and function could be demonstrated in cardiomyopathies and ischaemic heart disease. The present study was designed to evaluate mitral annulus (MA) morphology and function in young type 1 diabetes mellitus (T1DM) patients by three-dimensional speckle tracking echocardiography (3DSTE) and to compare their results to matched healthy controls.

Methods: The study comprised 18 patients with T1DM (mean age: 33.0±8.0 years). Their results were compared to that of 20 age- and gender-matched healthy controls (mean age: 37.8±10.9 years). Complete two-dimensional (2D) Doppler echocardiography and 3DSTE have been performed in all cases.

Results: No significant differences could be demonstrated in demographic and standard echocardiographic parameters between the groups. Significantly enlarged diastolic MA diameter (2.87±0.27 mm *vs.* 2.58±0.32 mm, *P*=0.01), MA diameter index 1.61±0.20 cm/m² *vs.* 1.30±0.39 cm/m², *P*=0.008, and MA area index (4.81±0.88 cm²/m² *vs.* 3.91±1.35 cm²/m², *P*=0.03) could be demonstrated in T1DM together with augmented MA fractional shortening (28.64±9.63% *vs.* 20.35±12.50%, *P*=0.05).

Conclusions: Early alterations in MA size and function could be demonstrated in young patients with T1DM by 3DSTE.

Keywords: Type 1 diabetes; mitral annulus (MA); three-dimensional; echocardiography

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Introduction

The mitral annulus (MA) separates the left atrium (LA) from the left ventricle (LV) and plays an important role in promoting LA and LV filling and emptying (1). The geometric shape of the MA approximates a hyperbolic paraboloid, which can be likened to a saddle (2). Alterations in MA size and function could be demonstrated in different clinical scenarios including different cardiomyopathies and ischaemic heart disease (3,4). Diabetes mellitus is a metabolic disease characterized by chronic hyperglycemia

which causes micro- and macrovascular complications. There is a high prevalence of DM among subjects with calcific aortic stenosis and MA calcification, as well (5). However, it would be important if early changes in MA morphology and function could be detected in type 1 diabetes mellitus (T1DM) before MA calcification occurs. Three-dimensional speckle tracking echocardiography (3DSTE) is a new clinical tool validated for LA and LV chamber quantifications and functional featuring (6,7). Moreover, its capability in reproducible assessment of MA dimensions allowing simple calculation of

LA ejection force has also been demonstrated (8). The present study designed to evaluate MA size and functional properties in young T1DM patients by 3DSTE and to compare their results to matched healthy controls.

Patients and methods

Patients population

The study comprised 18 non-obese patients with T1DM (mean age: 33.0 ± 8.0 years, 8 males, duration of T1DM: 17.3 ± 10.2 years, HbA1c: $8.2 \pm 1.8\%$, daily insulin dose: 37.6 ± 7.1 IU, body mass index: 24.1 ± 2.4 kg/m²) with subcutaneous insulin pump-treatment without cardiac symptoms. All T1DM patients with such treatment at the time of writing of the manuscript were involved into the present study from the patient population of the outpatient clinic of the diabetology division of the 1st Department of Medicine at the University of Szeged, Hungary. Their results were compared to 20 age- and gender-matched healthy controls (mean age: 37.8 ± 10.9 years, 9 males, body mass index: 25.3 ± 1.2 kg/m²). All subjects with known diseases or any condition which could affect the results were excluded from the control group. Healthy cases were primarily recruited on voluntary bases from the student and young fellows' population at our university. All T1DM patients and controls had undergone complete two-dimensional (2D) Doppler echocardiography and 3DSTE. American Diabetes Association (9) and World Health Organization (10) criteria were used for definition of T1DM. Systolic or diastolic elevation of the blood pressure ($>140/90$ mmHg) or ongoing antihypertensive therapy were used for definition of hypertension. A total cholesterol level >5.0 mmol/L or current treatment with lipid-lowering medications were used for definition of hypercholesterolaemia. Weight and height of all subjects were recorded and body surface area (BSA) was calculated by the standard formula ($\text{weight}^{0.425}$ in kilograms \times $\text{height}^{0.725}$ in centimeters $\times 0.007184$). All subjects have been included in the MAGYAR-Path Study (Motion Analysis of the heart and Great vessels bY three-dimensional speckle-tRacking echocardiography in Pathological cases) (11–13). This has been organized at the Cardiology Center of the University of Szeged, Hungary to evaluate clinical significance of 3DSTE-derived parameters in pathological cases ('magyar' means 'Hungarian' in Hungarian language). The Ethics Committee of the University of Szeged, Hungary, approved the study and informed consent was obtained from all participants (14).

2D echocardiography

All subjects underwent conventional 2D Doppler echocardiography, performed using a commercially available ultrasonic device (Toshiba ArtidaTM; Toshiba Medical Systems, Tokyo, Japan) with a PST-30SBP (1–5 MHz) phased-array transducer. LV diameters and volumes and LA diameter were measured in parasternal long-axis view and the method of Teichholz *et al.* was used for calculation of ejection fraction (15). Visual grading was used for quantification of mitral regurgitation (MR). MA diameter (MAD_{2D}) was obtained from an apical 4-chamber view at end-diastole (just before mitral valve closure).

3DSTE-derived mitral annular measurements

3DSTE-derived pyramidal datasets were acquired in the apical view using a fully sampled PST-25SX matrix-array transducer (Toshiba Medical Systems, Tokyo, Japan) (7,8,11–13,16). The depth and angle were adjusted in order to reach optimal temporal and spatial resolution. Full volume images were stitched from six subvolumes in six consecutive cardiac cycles. Measurements were performed using 3D Wall Motion Tracking software version 2.7. The apical two-chamber (AP2CH) and four-chamber (AP4CH) views and three short-axis views at different LV levels from the base to the apex were automatically selected from the 3D echocardiographic pyramidal dataset at end-diastole by the software. The Q7 short axis view was positioned at the level of MA in order to calculate morphological MA parameters. AP2CH and AP4CH views helped to find optimal endpoints of the MA. Measurements were made both at end-diastole and end-systole. The following measures were obtained (1,3,4,17) (Figure 1):

- (I) MA diameter (MAD_{3D}), defined as the perpendicular line drawn from the peak of MA curvature to the middle of the straight MA border both at systole and diastole;
- (II) MA diameter index (MADI_{3D}), defined as MAD_{3D}/BSA;
- (III) MA area (MAA_{3D}), measured at end-diastole (just before mitral valve closure) and at end-systole (just before mitral valve opening);
- (IV) MA area index (MAAI_{3D}), defined as MAA_{3D}/BSA;
- (V) MA perimeter (MAP_{3D});
- (VI) MA perimeter index (MAPI_{3D}), defined as MAP_{3D}/BSA;
- (VII) MA fractional shortening (MAFS_{3D}), defined as:

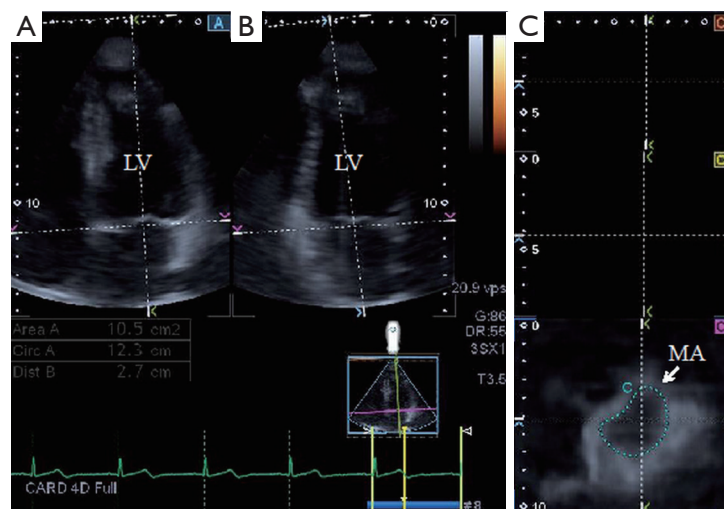


Figure 1 Images from three-dimensional full-volume dataset showing left ventricle (LV) in a patient with type 1 diabetes mellitus (T1DM): (A) apical four-chamber view, (B) apical two-chamber view and a cross sectional view at the level of the mitral annulus (MA) (C7) optimized on apical four- and two-chamber views.

$[(\text{end-diastolic MAD}_{3D} - \text{end-systolic MAD}_{3D}) / \text{end-diastolic MAD}_{3D} \times 100]$;

(VIII) MA fractional area change (MAFAC_{3D}), defined as: $[(\text{end-diastolic MAA}_{3D} - \text{end-systolic MAA}_{3D}) / \text{end-diastolic MAA}_{3D} \times 100]$.

Statistical analysis

Quantitative data were expressed as mean \pm standard deviation. For all analyses, two-sided $P < 0.05$ was defined as statistical significance. An independent-sample t -test was utilised for comparison between two groups. Categorical variables were compared using chi-square test and Fischer's exact test. Pearson's coefficient was calculated to examine correlations between MAD_{2D} and MAD_{3D} and MA and LV functional parameters. Commercially available MedCalc software was used for statistical calculations (MedCalc, Mariakerke, Belgium).

Results

Demographic and 2D echocardiographic data

No significant differences could be demonstrated in demographic and standard echocardiographic parameters between the groups (Table 1). No T1DM patients or healthy controls showed significant (\geq grade 1) MR. No calcification could be demonstrated in any of T1DM patients. Diastolic

MAD_{2D} of T1DM patients and controls was 2.70 ± 0.21 cm and 2.47 ± 0.26 cm, respectively ($P = 0.05$). Systolic MAD_{2D} of T1DM patients and controls was 2.01 ± 0.15 cm and 2.03 ± 0.18 cm, respectively ($P = 0.81$).

3DSTE-derived MA parameters

Significantly enlarged diastolic MA diameter, MA diameter index and MA area index could be demonstrated together with augmented MAFS_{3D} in T1DM patients as compared to age- and gender matched healthy controls (Table 2).

Correlations between MAD_{2D} vs. MAD_{3D}

Measurements of MAD_{2D} and MAD_{3D} were well correlated both in T1DM patients and controls ($r = 0.80$, $P < 0.01$ and $r = 0.81$, $P < 0.01$, respectively).

MA function and LV function

MAFAC_{3D} did not correlate with LVEF_{2D} in any subjects or patients. MAFS_{3D} correlated with LVEF_{2D} in control subjects ($r = 0.50$, $P = 0.03$).

Discussion

Morphologic and functional aspects of the MA in young patients with T1DM were assessed by 3DSTE in the

Table 1 Baseline demographic and 2D echocardiographic data in patients with T1DM and controls

Parameters	T1DM patients (n=18)	Controls (n=20)	P value
Risk factors [%]			
Age (years)	33.0±8.0	37.8±10.9	0.15
Male gender	8 [44]	9 [45]	1.00
Hypertension	4 [22]	0 [0]	0.04
Diabetes mellitus	18 [100]	0 [0]	<0.0001
Hypercholesterolaemia	4 [22]	0 [0]	0.04
2D echocardiography			
LA diameter (mm)	33.6±6.6	34.2±2.9	0.74
LV end-diastolic diameter (mm)	46.3±5.7	47.7±6.1	0.43
LV end-diastolic volume (mL)	100.7±29.1	101.0±19.3	1.00
LV end-systolic diameter (mm)	29.4±4.6	30.3±4.1	0.62
LV end-systolic volume (mL)	34.4±12.4	35.0±10.9	0.93
Interventricular septum (mm)	9.00±1.88	9.46±2.01	0.49
LV posterior wall (mm)	9.04±0.90	9.50±2.35	0.47
LV ejection fraction (%)	65.9±7.9	66.3±6.9	0.94
E/A	1.50±0.49	1.33±0.11	0.10

T1DM, type 1 diabetes mellitus; LA, left atrial; LV, left ventricular; 2D, two-dimensional.

present work. To the best of authors' knowledge this is the first study in which early alterations in MA size and function could be detected in young T1DM patients without MR/valvular calcifications by 3DSTE. Enlarged diastolic MA dimensions and augmented MA function could be demonstrated as compared to matched healthy controls.

Several methodologies including different echocardiographic techniques (1,18,19), computer tomography (CT) (20) and cardiac magnetic resonance imaging (cMRI) (21) could be used for non-invasive quantification of MA size and function. Volumetric real-time 3D echocardiography (RT3DE) and real-time 3D transesophageal echocardiography (RT3DTEE) has been demonstrated to be useful for non-(semi-)invasive estimation of MA morphology and functional properties (1,3,4,17,19). 3DSTE seems to be a promising tool

Table 2 3DSTE-derived MA morphological and functional parameters in with T1DM and controls

Parameters	T1DM patients (n=18)	Controls (n=20)	P value
Diastolic morphological parameters			
Diastolic MA diameter (cm)	2.87±0.27	2.58±0.32	0.01
Diastolic MA diameter index (cm/m ²)	1.61±0.20	1.30±0.39	0.008
Diastolic MA area (cm ²)	8.61±1.57	7.82±1.83	0.18
Diastolic MA area index (cm ² /m ²)	4.81±0.88	3.91±1.35	0.03
Diastolic MA perimeter (cm)	10.76±1.05	10.45±1.19	0.43
Diastolic MA perimeter index (cm/m ²)	6.02±0.77	5.23±1.44	0.06
Systolic morphological parameters			
Systolic MA diameter (cm)	2.04±0.26	2.07±0.30	0.74
Systolic MA diameter index (cm/m ²)	1.14 ±0.15	1.08±0.17	0.37
Systolic MA area (cm ²)	4.86±1.17	4.61±0.94	0.49
Systolic MA area index (cm ² /m ²)	2.71±0.60	2.41±0.47	0.12
Systolic MA perimeter (cm)	8.18±1.03	7.96±0.85	0.50
Systolic MA perimeter index (cm/m ²)	4.57±0.62	4.19±0.54	0.06
Systolic functional parameters (%)			
MA fractional area change	42.22±15.51	40.06±12.49	0.65
MA fractional shortening	28.64±9.63	20.35±12.50	0.05

T1DM, type 1 diabetes mellitus; MA, mitral annulus; 3DSTE, three-dimensional speckle tracking echocardiography.

based on “block-matching” algorithm by strain analysis for evaluation of atrial and ventricular volumes, strains, rotational and dyssynchrony parameters (7,8,12,13,16). In a recent study capability of 3DSTE in reproducible assessment of MAD and MAA has also been confirmed (8). 3DSTE-derived MA parameters, especially MAD however, showed somewhat lower values as demonstrated before for that of healthy subjects by RT3DE (17). However, in other 2D echocardiographic studies, MAA values were in

the similar range as in the present 3DSTE study (22,23). Our results could be explained by 3DSTE-related technical limitations including low image quality and temporal and spatial resolutions. Moreover, definition of normal MA is quite variable, probably caused by the complex 3D saddle-shaped geometry of the MA, which could give an opportunity for inadequate positioning of the cross-sectional plane on it during measurements (17). These facts could lead for underestimation of MA parameters. It should also be taken into consideration that mostly young patients without any risk factors or other conditions were involved into the study. Theoretically there were no reasons for MA dilatation or functional alterations in these cases. Results could highlight on the importance on additional validation of the method which requires serial comparative studies with other imaging methodologies.

In recent studies, despite MA dilatation in patients with hypertrophic cardiomyopathy (HCM) and dilated cardiomyopathy (DCM), MA function was found to be augmented in HCM patients and impaired in DCM patients as assessed by RT3DE-derived MAFAC and MAFS (3). Similar alterations could be detected in noncompaction cardiomyopathy (NCCM): MA dilatation was associated with decreased MA functional properties by RT3DE (4). It is also known, that calcification within the MA results from a degenerative process in the cardiovascular fibrous skeleton, which is reported to be accelerated by several risk factors including DM (24,25). With the present study, MA dilatation and compensating enhancement in MA function could be demonstrated in young T1DM patients before MA calcification would have been developed. These findings could draw our attention on the fact, that valvular remodeling starts even in younger ages with compensating functional alterations in T1DM. However, further studies are warranted to confirm our findings focusing on clinical implications.

Limitation section

The following important limitations should be taken into consideration over mentioned above:

- (I) 3DSTE has been demonstrated to be suitable for the evaluation of volumetric, strain, rotational and dyssynchrony parameters of different heart chambers. However, the present study did not aim to analyse these parameters;
- (II) Higher grade of MR should have affected results. However, none of T1DM patients and controls had

≥ grade 1 MR;

- (III) A limited number of T1DM patients and controls were examined and compared in this study. This fact should be taken into consideration when interpreting results;
- (IV) Patients in non-sinus rhythm would have been excluded due to the nature of 3DSTE. However, all subjects were in sinus rhythm;
- (V) Further validation studies are warranted for the usefulness of 3DSTE in the evaluation of valvular morphology and functional properties.

Conclusions

Early alterations in MA size and function could be demonstrated in young patients with T1DM by 3DSTE.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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